

# **FUNDAMENTAL TECHNOLOGY DEVELOPMENT FOR SPACE SCIENCE**

SEU/Origins Subcommittee Meeting

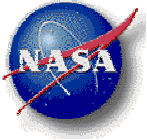
July 2, 2003

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# Outline



- 
- Code R Technology Programs
  - Addressing Code S Needs
  - Sensor Technology
    - Direct detectors and focal planes
    - Cryocoolers
    - Terahertz receivers
  - Large Aperture Technology
    - Dual Anamorphic Reflector Telescope (DART)
  - Distributed Spacecraft Technology
  - Code R NASA Research Announcements



# The Aerospace Technology Enterprise Contributes to the NASA Vision and Mission through Technology Development and Transfer

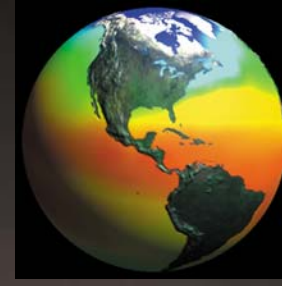
## NASA's Vision



**OGA & Industry  
Partners**



**Space  
Science**



**Earth  
Science**



**Biological &  
Physical  
Research**



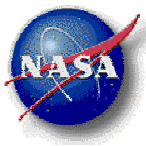
**Non Aerospace  
Industry & Educators**



**Aerospace  
Technology**



**Space Flight**



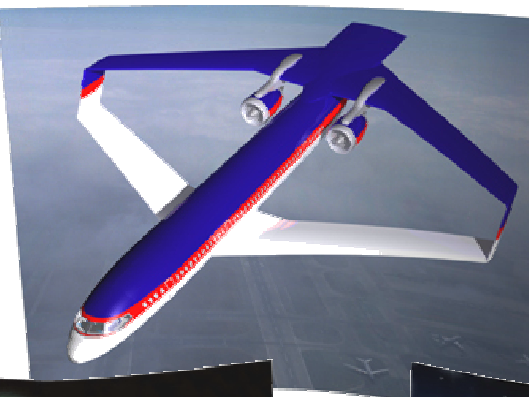
# Aerospace Technology Enterprise

## Strategic Themes

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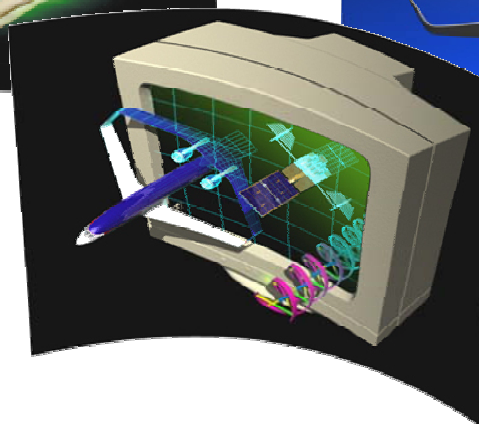
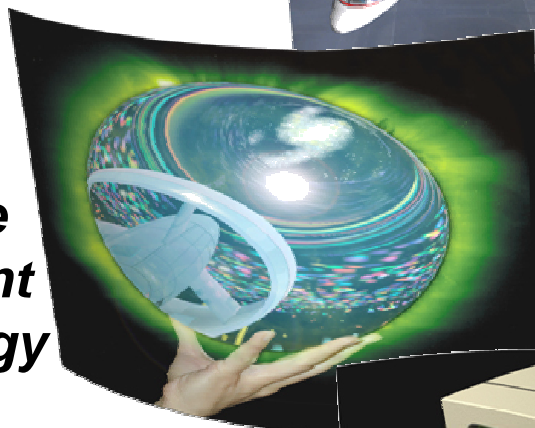
***Aeronautics  
Technology***



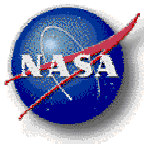
***Space Launch  
Initiative***



***Mission and  
Science  
Measurement  
Technology***



***Innovative Technology  
Transfer Partnerships***



# Mission & Science Measurement Technology

Strategic Theme Objectives and Programs



## Theme Objectives

### Mission Risk Analysis

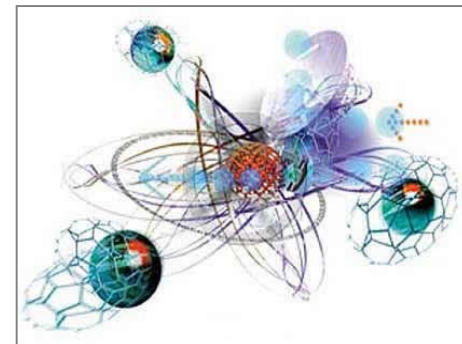
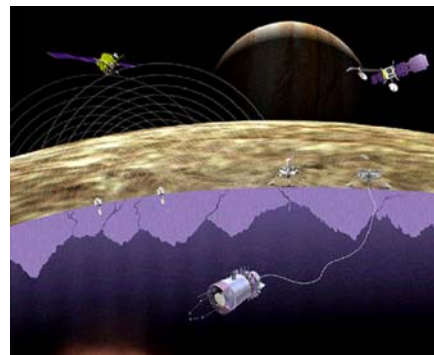
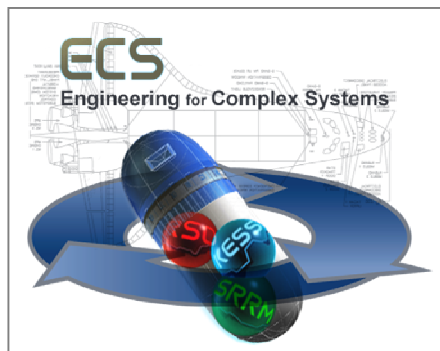
Develop the capability to assess and manage risk in the synthesis of complex systems.

### Science Driven Mission Architectures and Technology

Define new system concepts and demonstrate new technologies which enable new science measurements.

### Create Knowledge from Scientific Data

Develop break-through information and communication systems to increase our understanding of scientific data and phenomena



## Programs

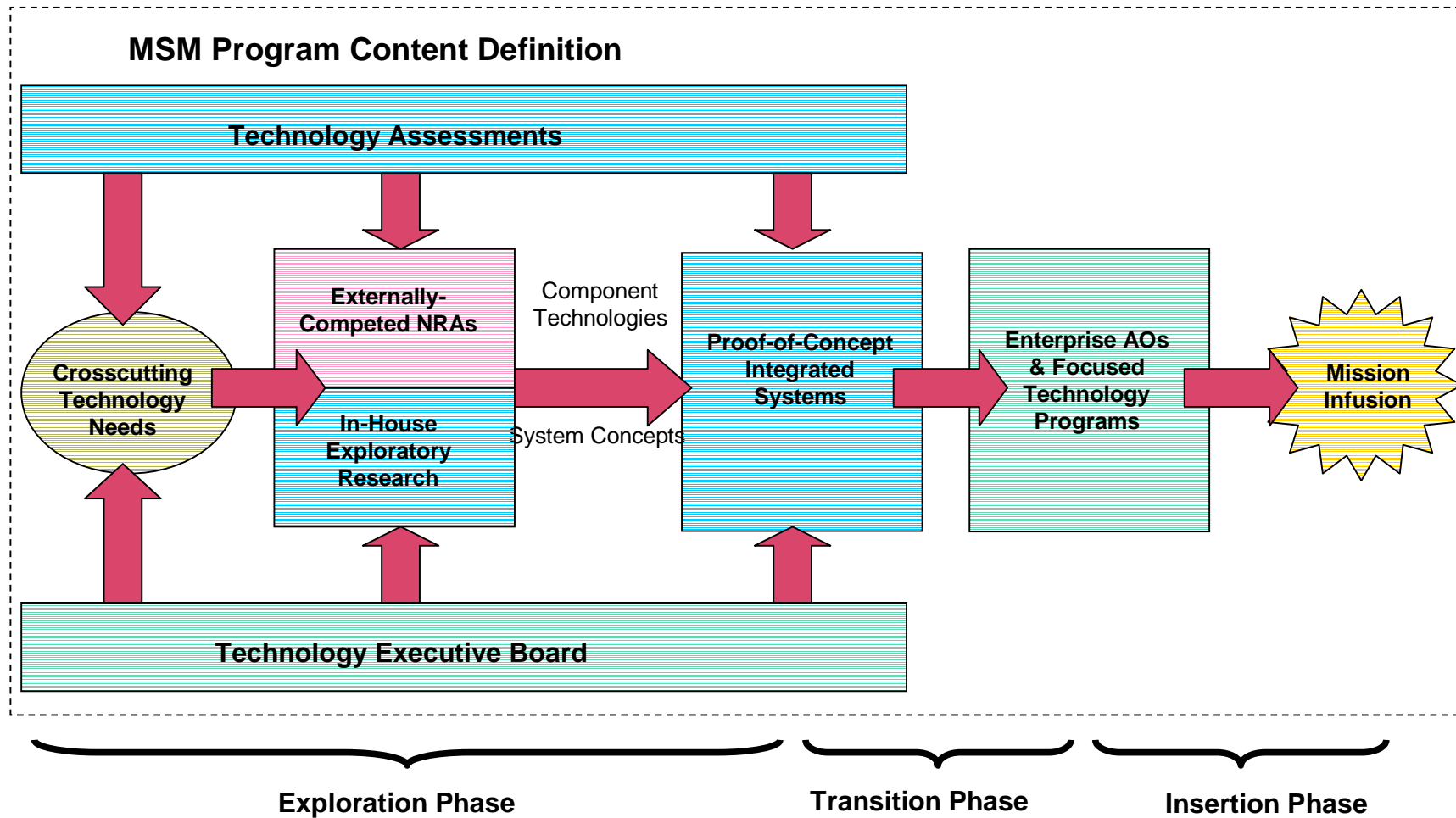
**Engineering for Complex Systems**

**Enabling Concepts & Technologies**

**Computing, Information & Communications Technology**

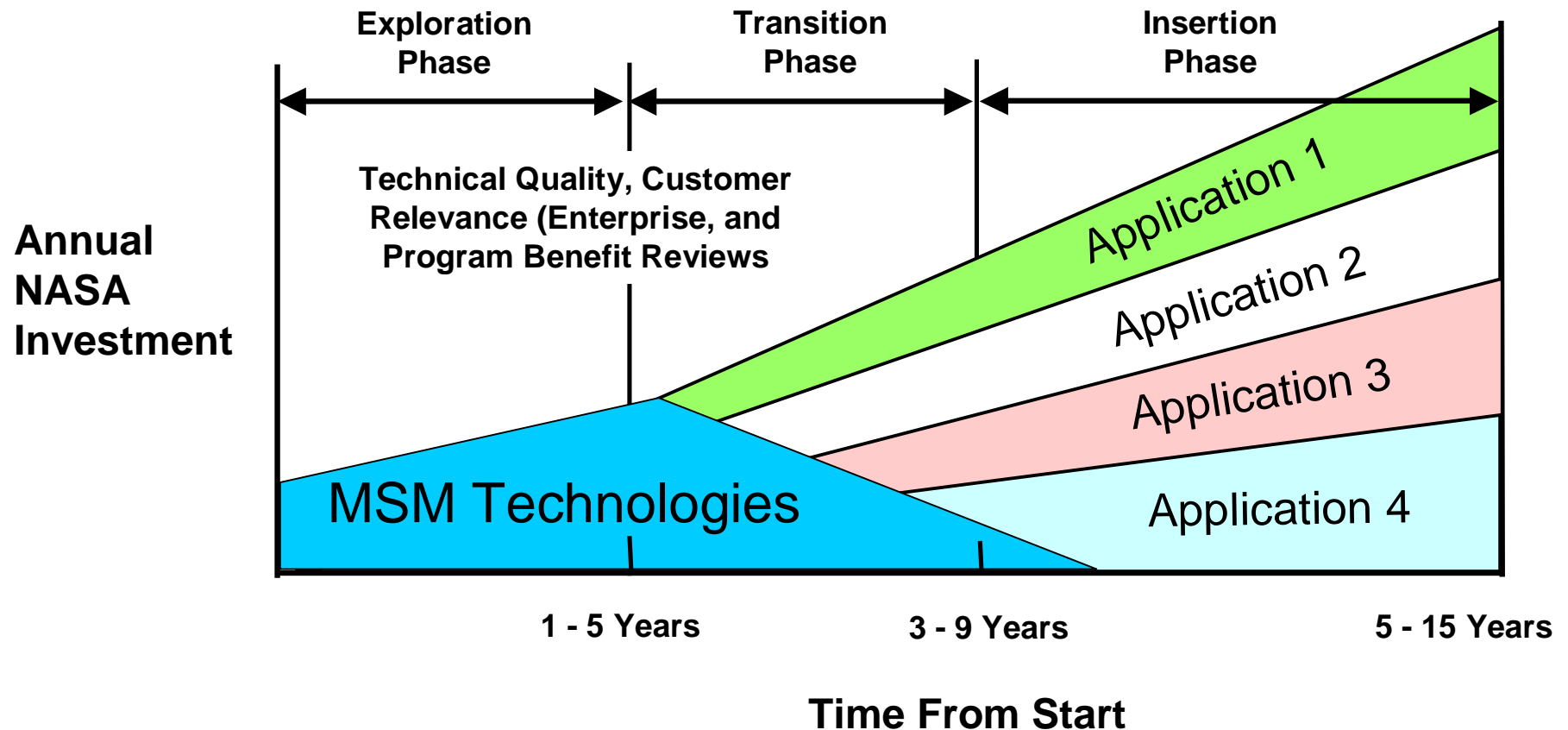


# Program Implementation Strategy





# The Big Picture - Where MSM Fits





# Addressing Enterprise Technology Needs



- Code R has established a Technology Executive Board (TEB)
  - Membership - Enterprise Technology Representatives
  - Establish joint list of Enterprise technology needs and priorities
  - Provide guidance on program content and direction
  - Ensure technology infusion
  - Integrate/coordinate Code R with Enterprise specific initiatives

## Code S

- Sensors and instruments
- Advanced optical systems
- Robotic systems
- High strength-to-weight materials
- Advanced propulsion
- Formation flying
- Extreme environments

## Code M

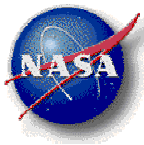
- Large space solar power systems
- High power propulsion
- Modular infrastructures
- Assembly, maintenance, & servicing
- Lighter, more flexible EVA with extended duration

## Code Y

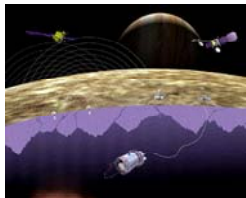
- Lasers and lidar
- Large telescopes & antennas
- Frequency agile detectors
- Microwave transmitters & receivers
- High efficiency solar cells
- Miniature guidance & navigation sensors

## Code U

- Autonomous environmental monitoring & control
- In-space medical diagnostics
- Spectroscopy for space biology research
- Biomolecular sensors to support crew health & safety
- Lighter, more flexible EVA with extended duration
- In-space manufacturing & fabrication

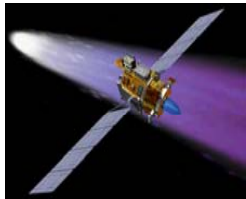


# Enabling Concepts & Technologies Program Projects



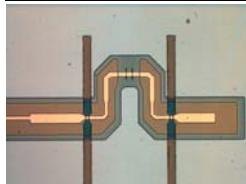
## Advanced System Concepts

*Conceptual studies and systems analysis of revolutionary aerospace system concepts that have the potential to leap well past current plans, or to enable new visions for NASA's strategic plans.*



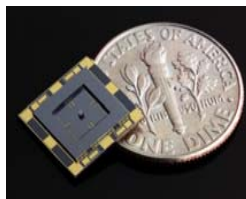
## Energetics

*Development of advanced power and propulsion technologies to enable lower-cost missions with increased capability, and to extend mission reach.*



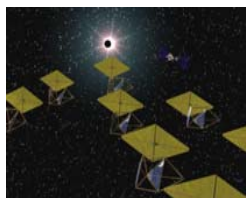
## Advanced Measurement and Detection

*Development of miniaturized, highly-integrated, and efficient instruments and sensors to provide increased scientific return.*



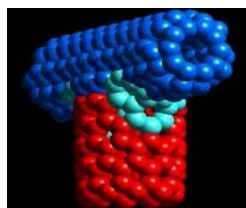
## Revolutionary Spacecraft Systems

*Development of revolutionary spacecraft systems and architectures to enable distributed science data collection, explore extreme environments, and lower mission costs.*



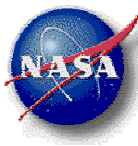
## Large Space Systems

*Development of concepts for large, ultra-lightweight space structures and apertures to expand mission capabilities, and enable new visions of the Earth and the Universe.*



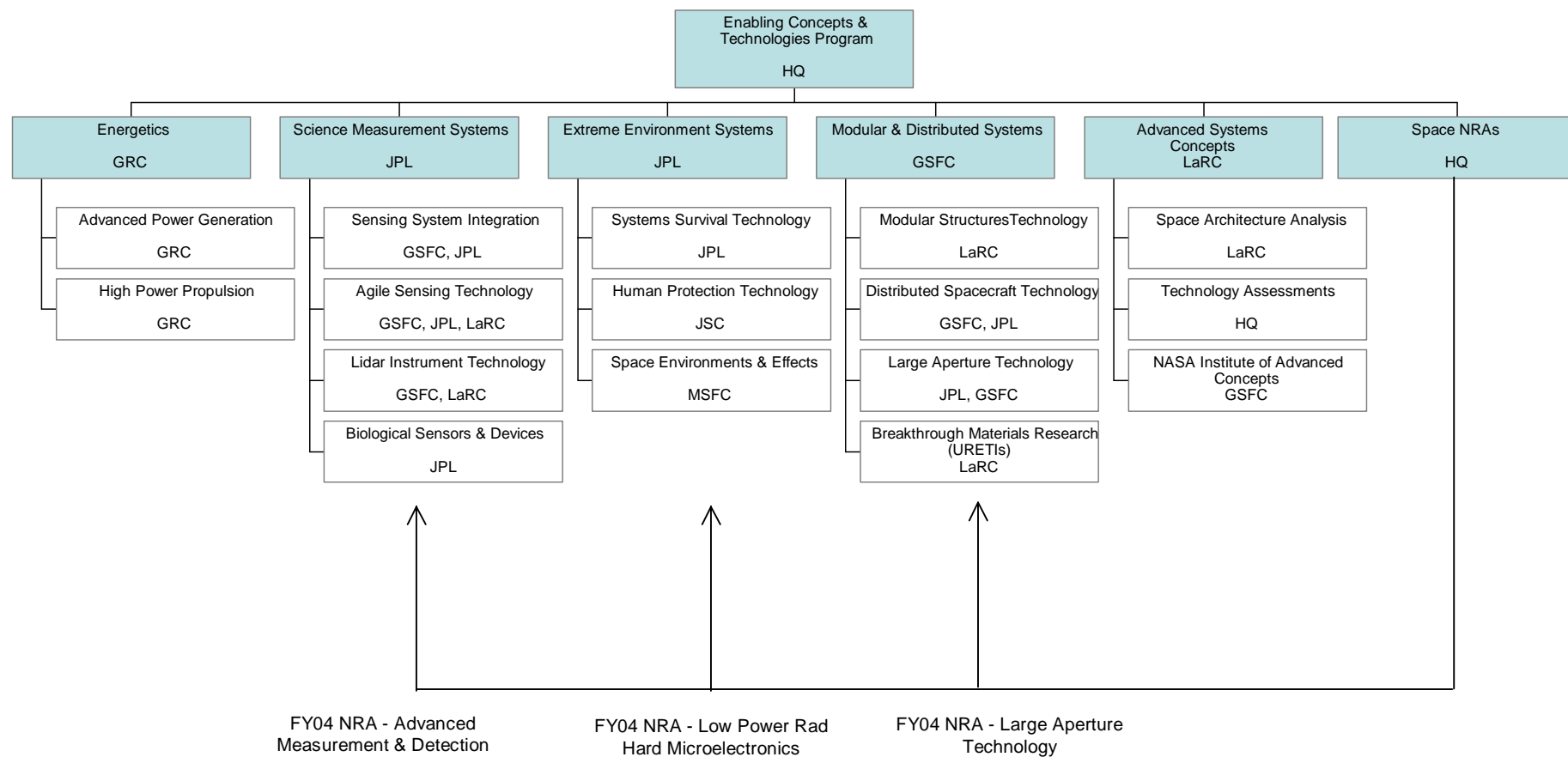
## Space NRAs

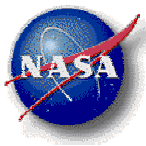
*Broadly announced peer-reviewed solicitations to capture innovative ideas from external organizations, to leverage high-payoff emerging technologies, and to complement NASA capabilities in critical areas.*



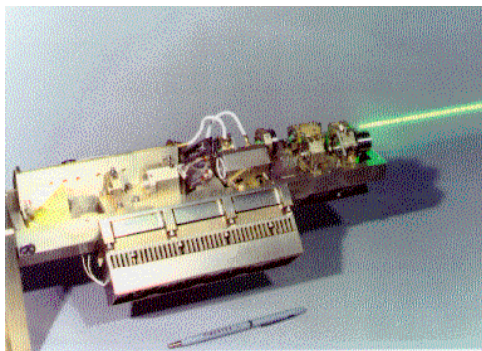
# Enabling Concepts & Technologies Program

## FY05 Project Organization

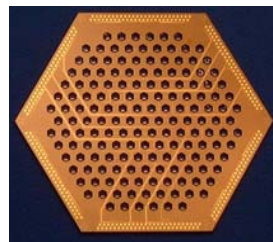
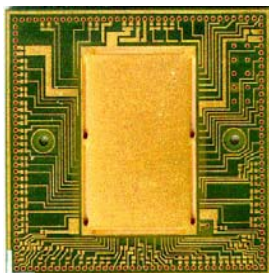




# Advanced Measurement & Detection Technology Products



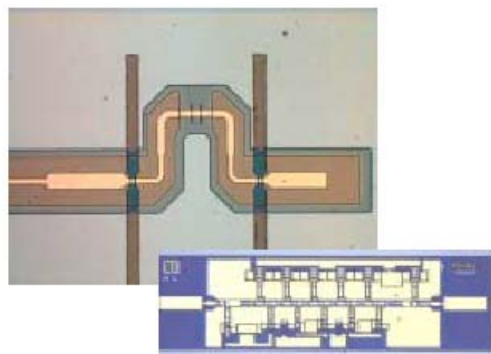
High efficiency, tunable laser transmitters for active sensing



High efficiency detectors (IR, visible, UV, X-ray) for focal plane assemblies



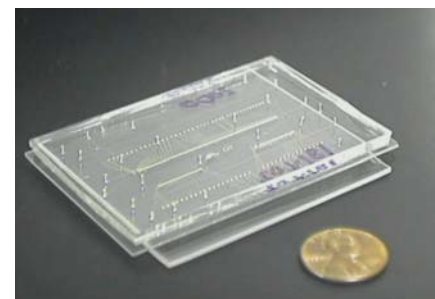
Instrument optics



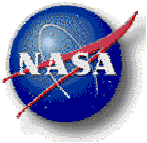
Submillimeter sources, amplifiers, and detectors



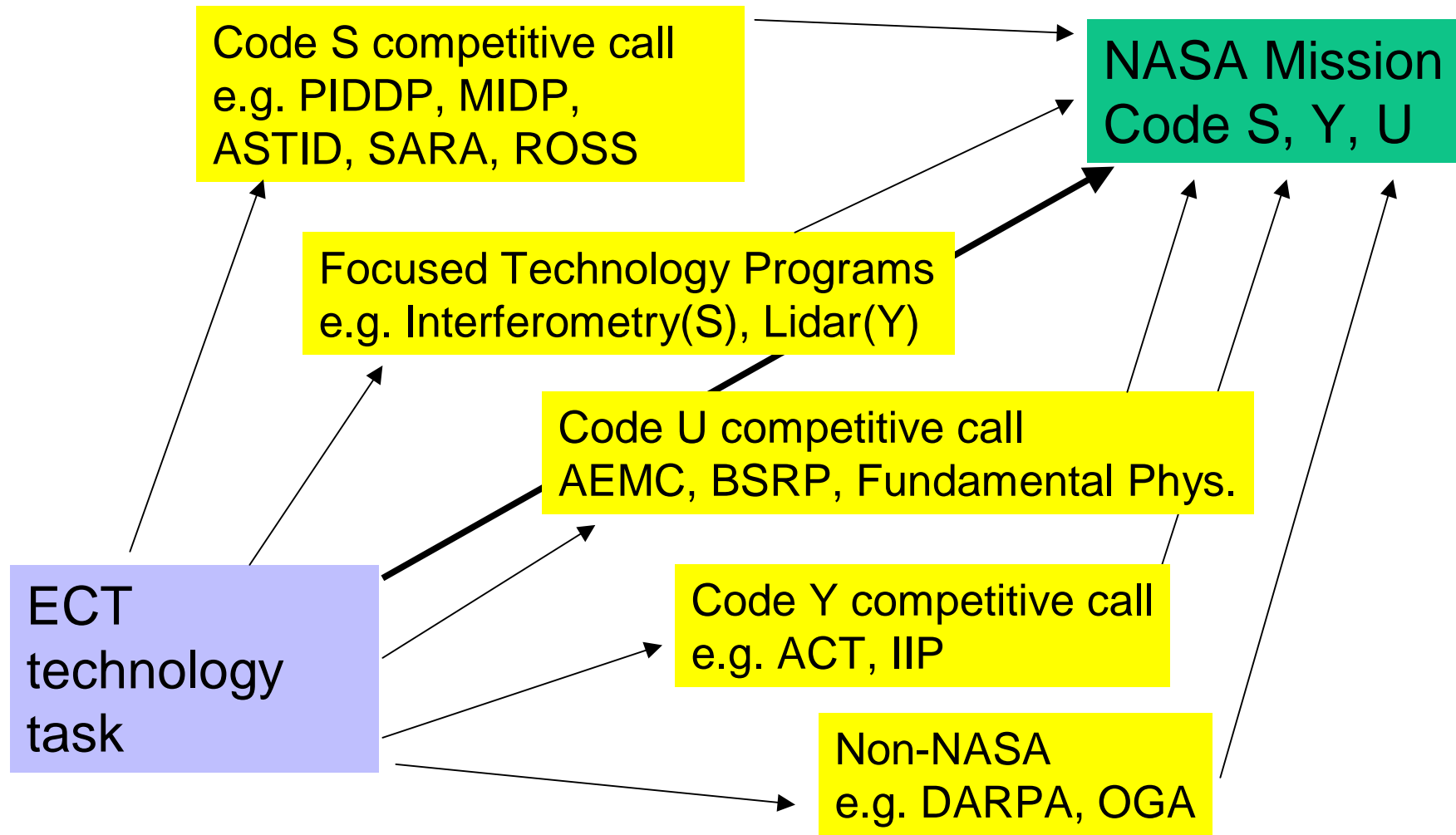
Cryocoolers

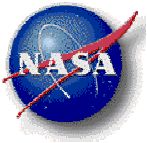


In situ biological & chemical sensors

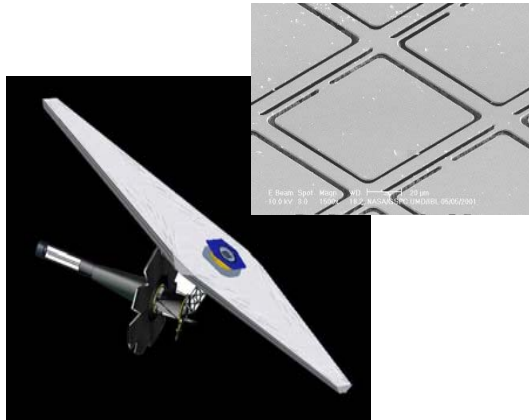


# Transition Paths for Code R Technology

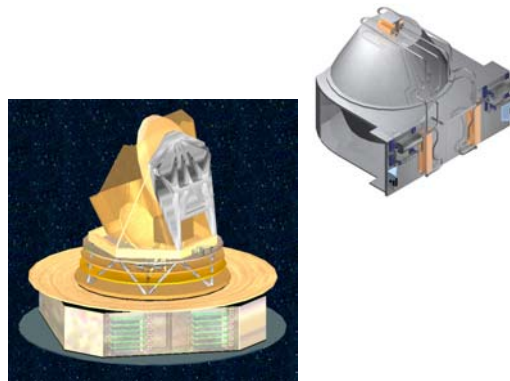




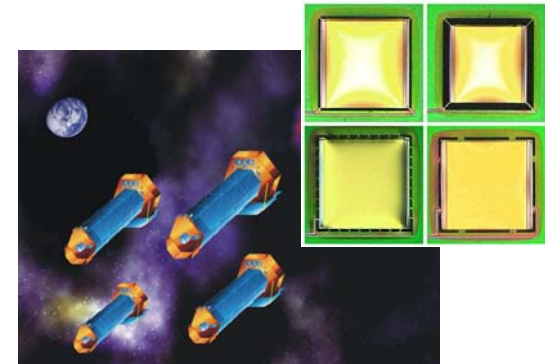
# Code R Technology Directly Inserted into NASA missions



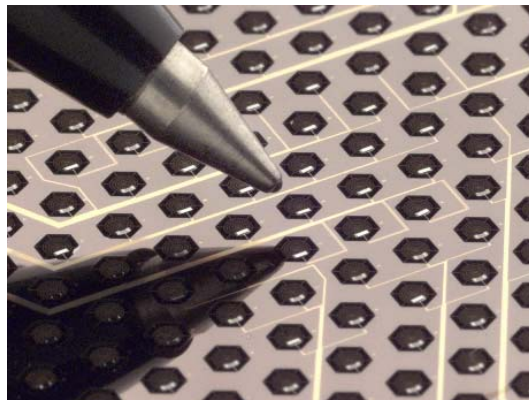
MEMS Micro-shutter Array for  
James Webb Space Telescope  
multi-object spectrometer



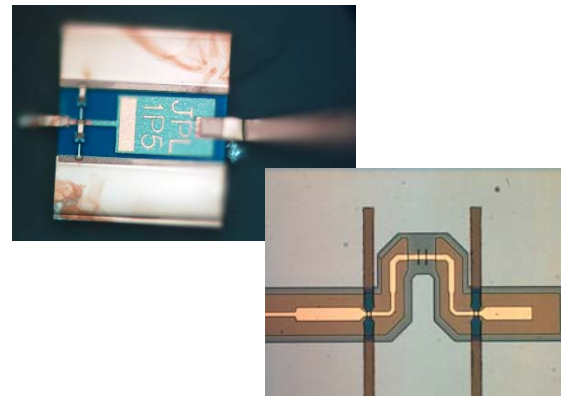
Zero vibration 20K helium  
sorption cooler for Planck



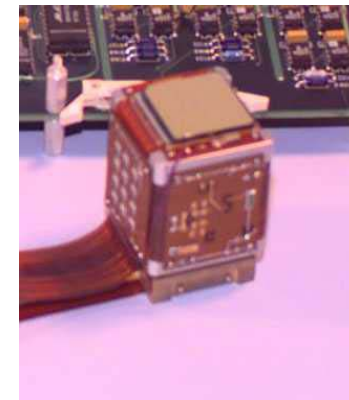
Superconducting Transition  
Edge Sensor array for  
Constellation-X



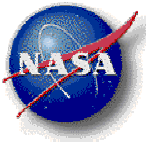
Micromesh bolometer arrays  
for Herschel and Planck



Superconducting mixers and  
planar multipliers for Herschel,  
Planck, and SOFIA



CZT Hard X-ray focal  
planes for Constellation-X



# Direct Detectors and Focal Planes



## Visible

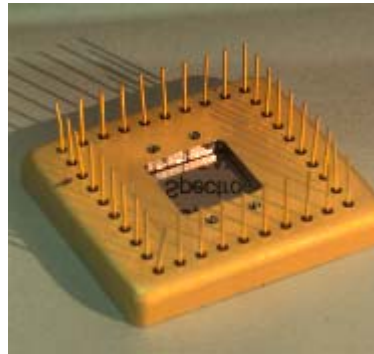
Science Grade CCDs  
CMOS Active Pixel Sensors



CMOS APS “camera on a chip”

## Ultraviolet

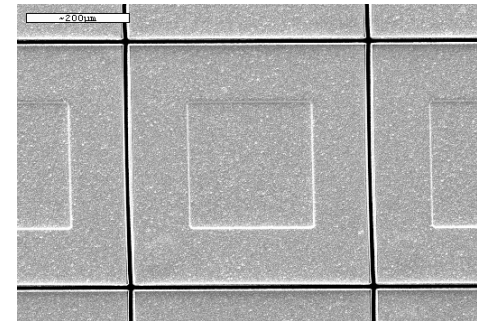
GaN Staring Hybrid FPAs  
Delta-doped SiCCDs



Delta-doped UVCCD

## X-ray

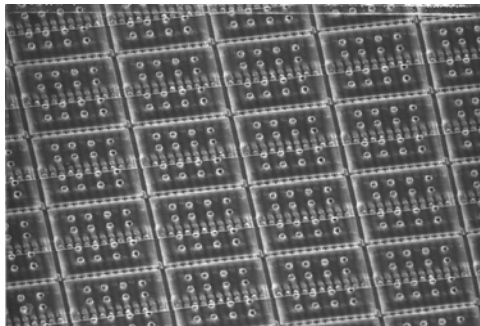
Transition Edge Calorimeters  
CZT Staring Hybrid FPAs



TES pixels

## MW/LW Infrared

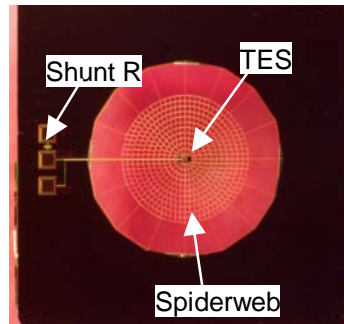
Uncooled IR thermopiles  
Quantum dot IR photodetectors



2D Thermopile Array

## Far Infrared

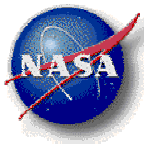
Micromesh Bolometer Arrays  
Superconducting TES and Kinetic Inductance



Superconducting TES bolometer



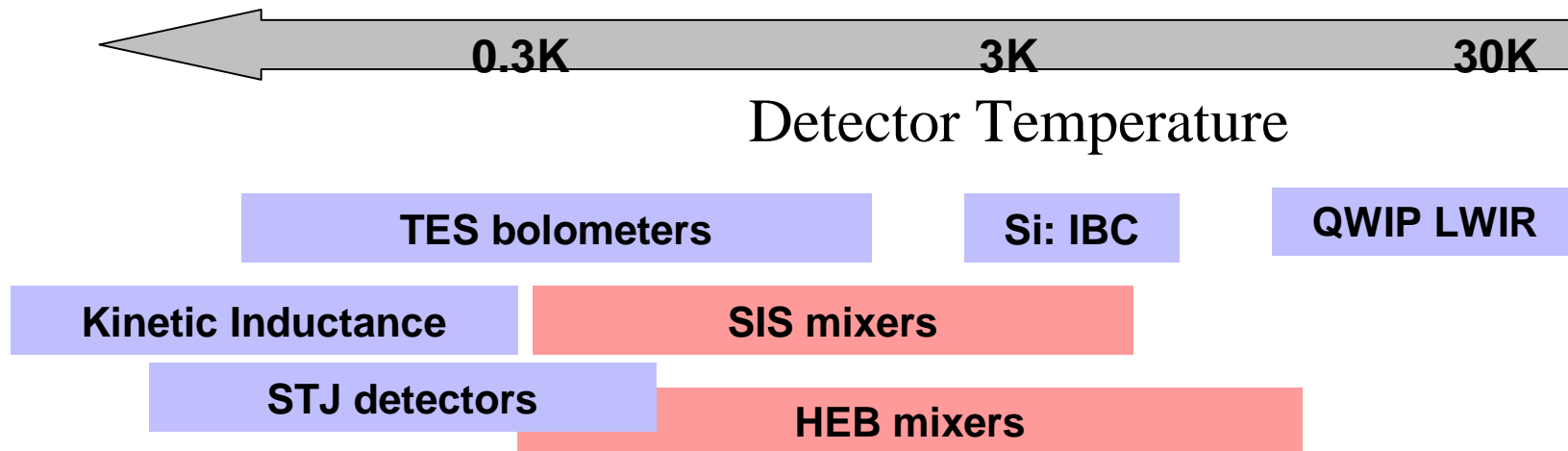
Kinetic Inductance Detector



# Cryogenic Technology

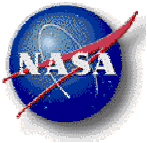


Improvement in Cryogenic Technology is **CRITICAL** to allow advancements in high performance focal planes and RF/THz receivers.



## Keys for development in this area

- Cooling power consistent with focal plane or mixer
- Vibrationless methods to reduce microphonic noise
- Ability to reject heat appropriately and mesh with other stages of cooling system



# Cryogenic Coolers



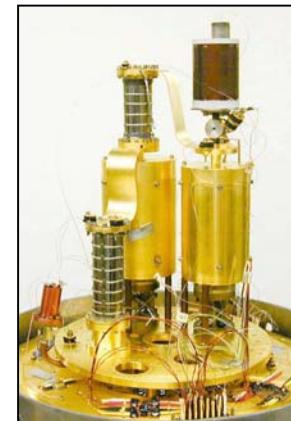
**20K Pulse Tubes with  
Advanced Regenerators**



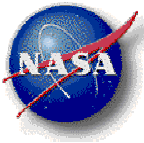
**4 - 10K  
Turbo-Brayton**



**20K and 6K Sorption  
Coolers**



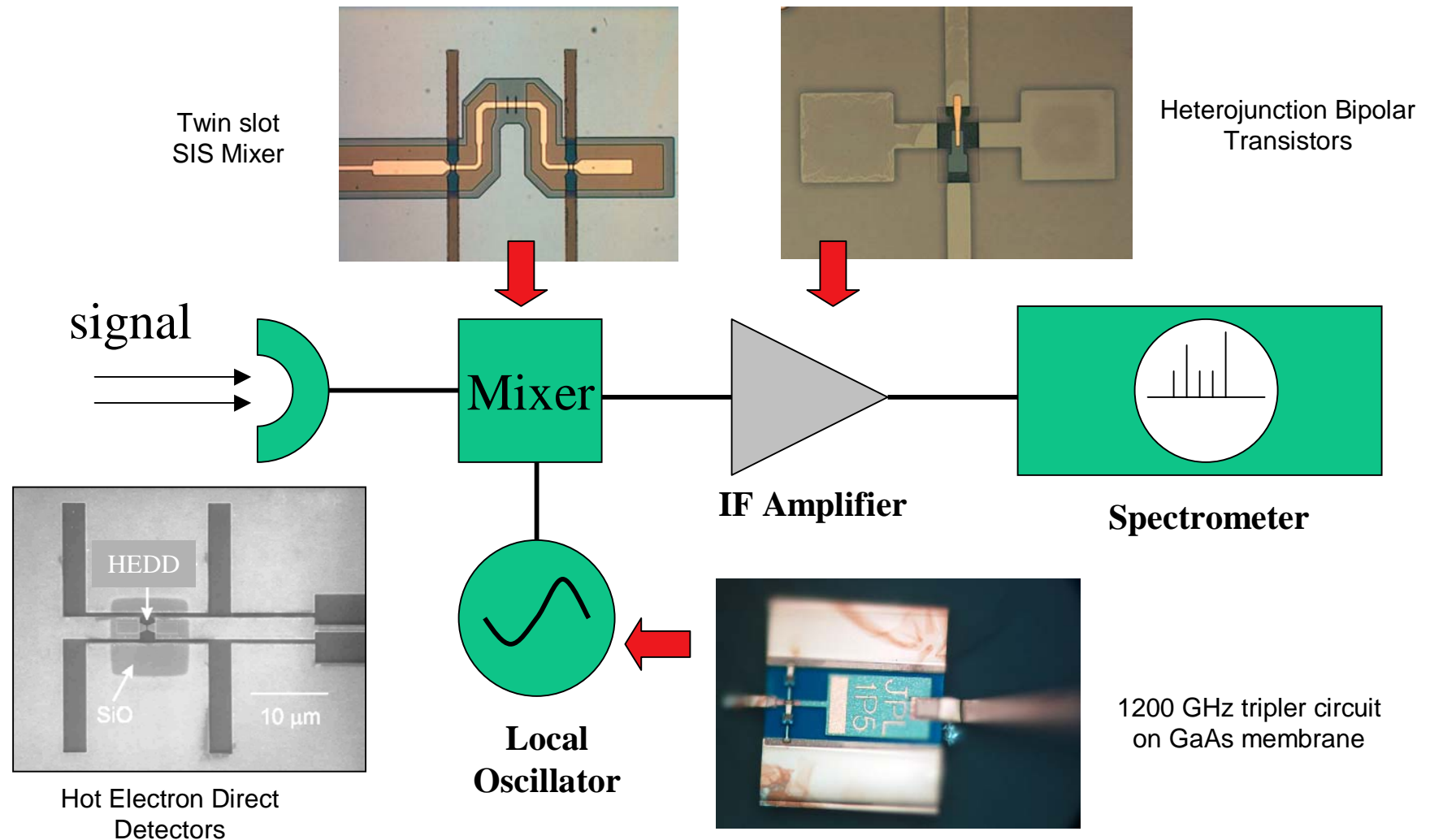
**50mK Adiabatic Demagnetization  
Refrigerators**



# Terahertz Technologies

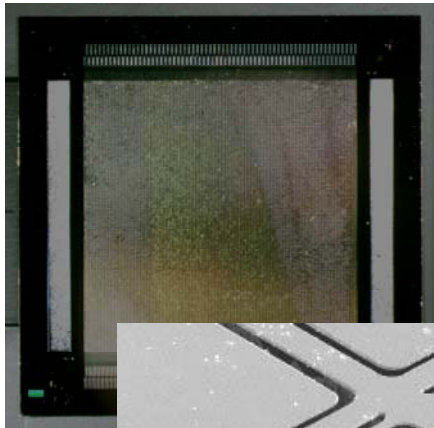


## Superconducting mixers / sources / amplifiers for THz heterodyne receivers THz detector arrays

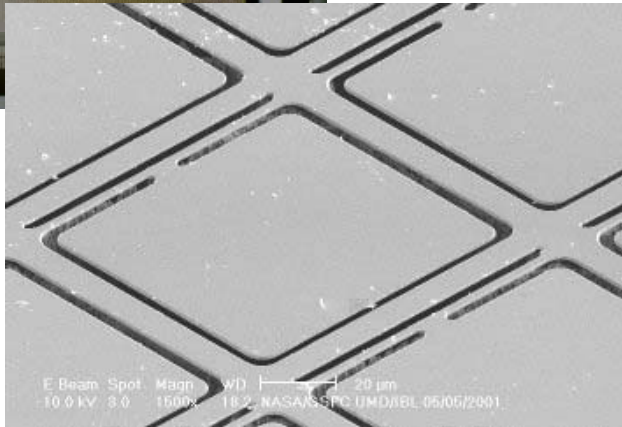




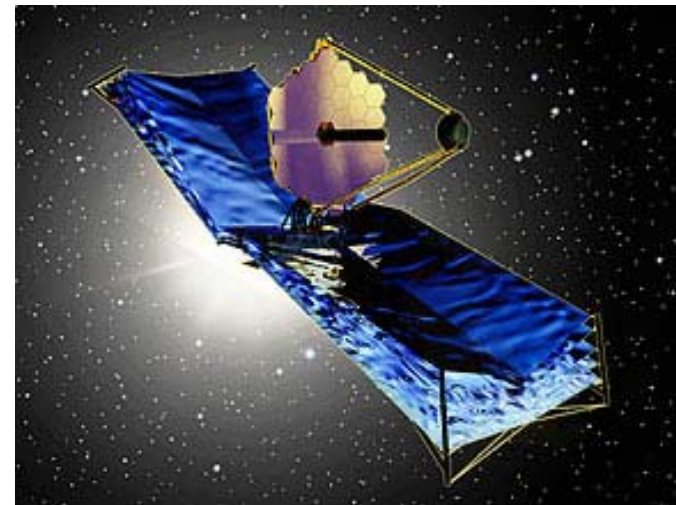
# MEMS-Based MicroShutter Array



128 x 128  
shutter array



Selected for James Webb Space Telescope  
Multi-Object Spectrometer instrument.

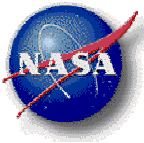


## Participants

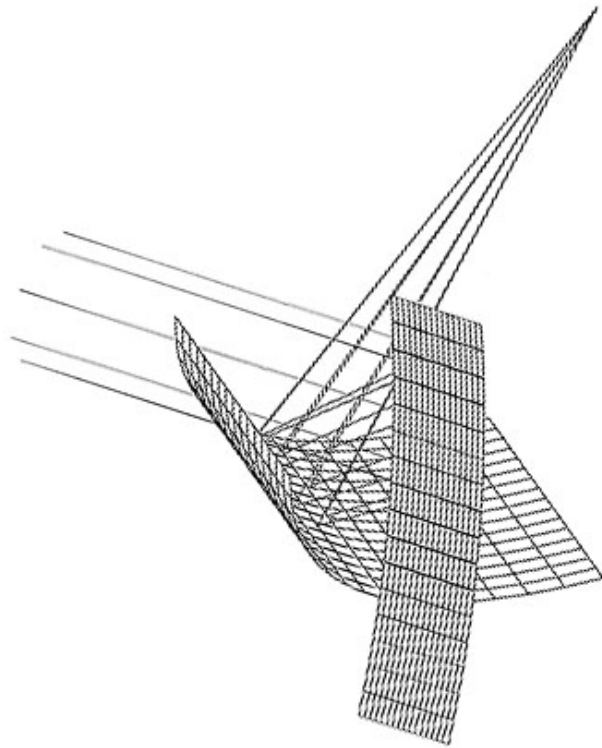
Principal Investigator - H. Moseley, NASA/GSFC  
Task Manager - J. Hein, NASA/GSFC  
Partners - Naval Research Lab, Applied Physics  
Lab, JPL, U. of MD, Penn State, VA Tech

## Objectives

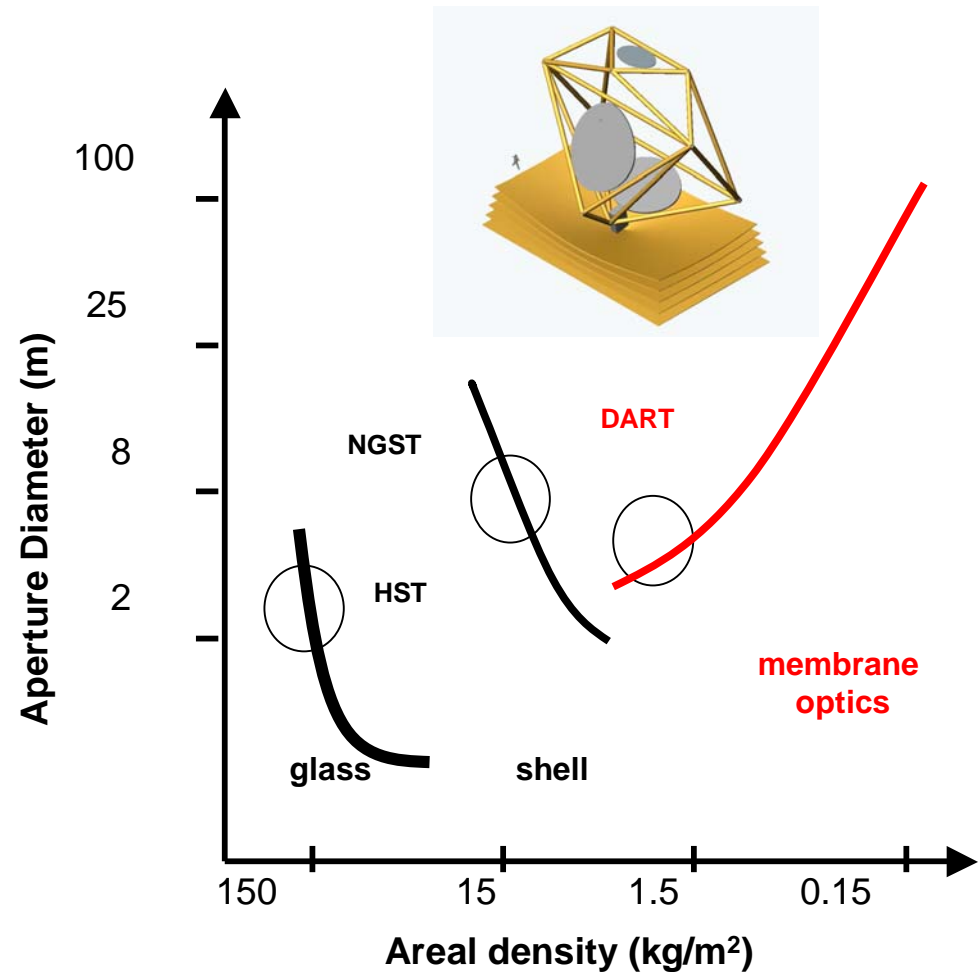
A transmissive field selector  
Cell Size: 100mm square  
Operation Temp. 30-35K  
Reliability:  $10^6$  cycles  
Power: 35mW avg. dissipation



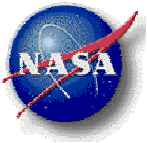
# Dual Reflector Anamorphic Telescope (DART)



Two cylindrical reflectors are oriented perpendicular to each other with slightly different focal lengths so that both focus at the same point.



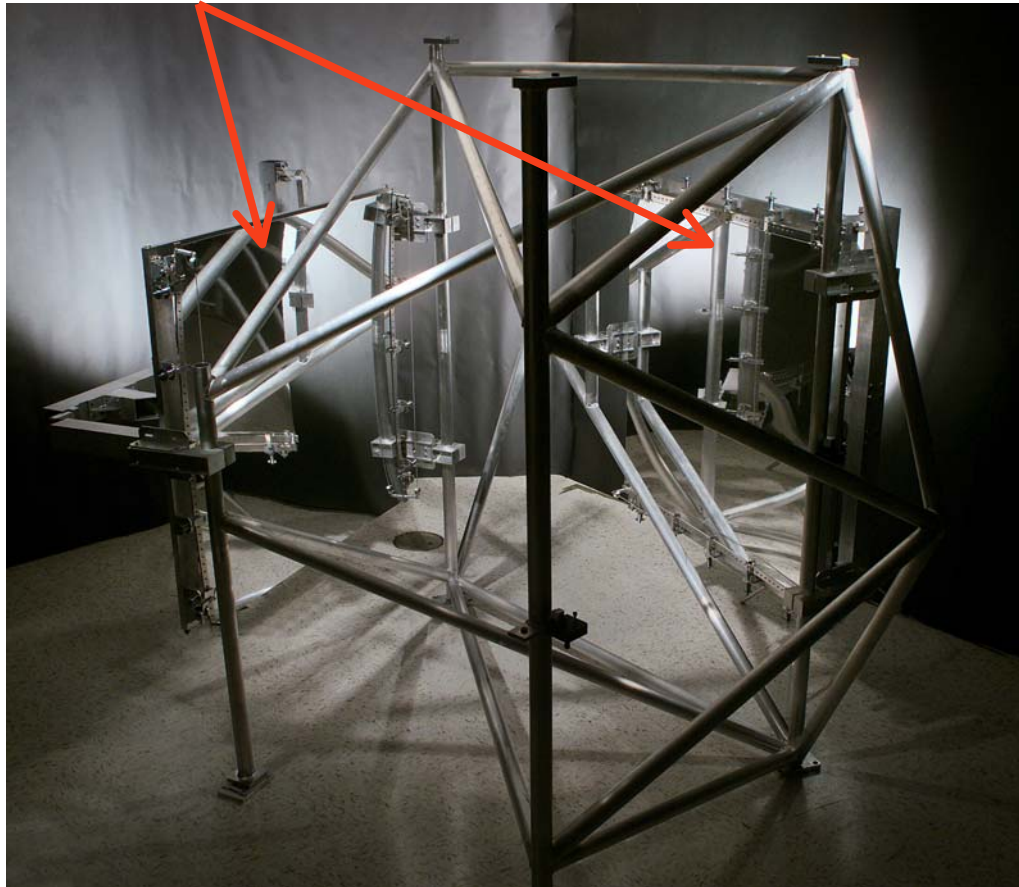
System areal density decreases with increasing aperture size.



# DART Prototype



Membrane  
reflectors



1.2 m DART prototype achieved  
diffraction limited performance at  $40\ \mu\text{m}$   
(Lockheed Martin / JPL)

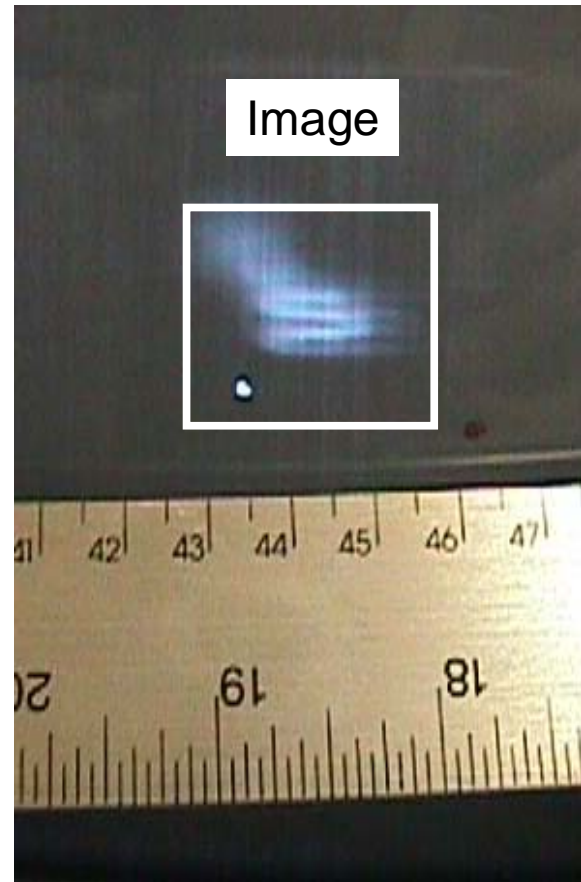
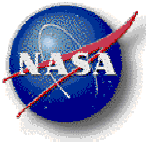


Image at DART focal plane



# DART Work in Progress

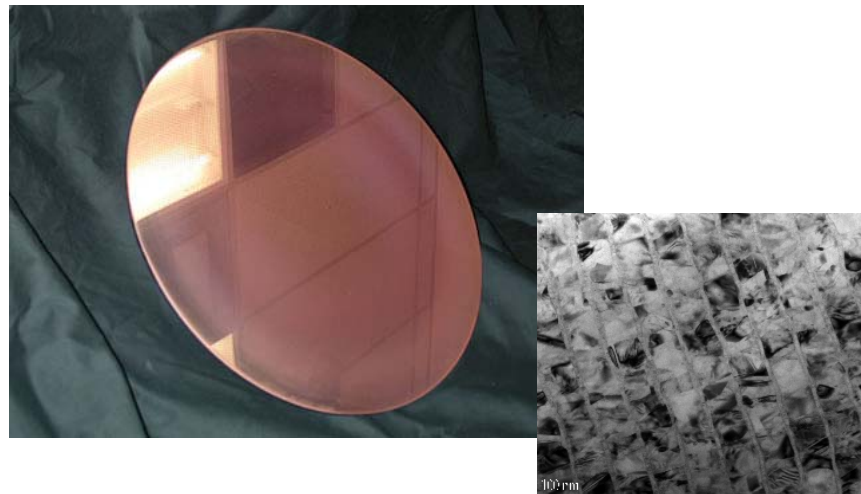


## JPL:

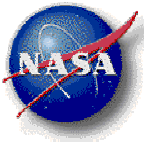
- 0.5 m precision testbed with actuators for figure control
- Scale-up of membrane materials (nanolaminate, polymer film)
- Integrated optical/structural model
- Membrane metrology

## Lockheed Martin:

- 2m x 4m scaled testbed
- Full aperture optical testing of 1.2 m testbed



Nanolaminate membrane reflector



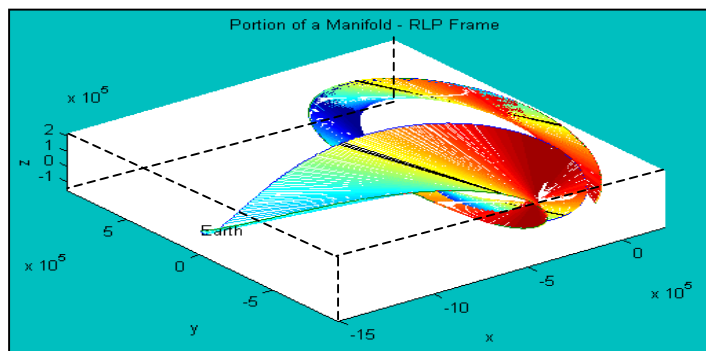
# Distributed Spacecraft Technologies



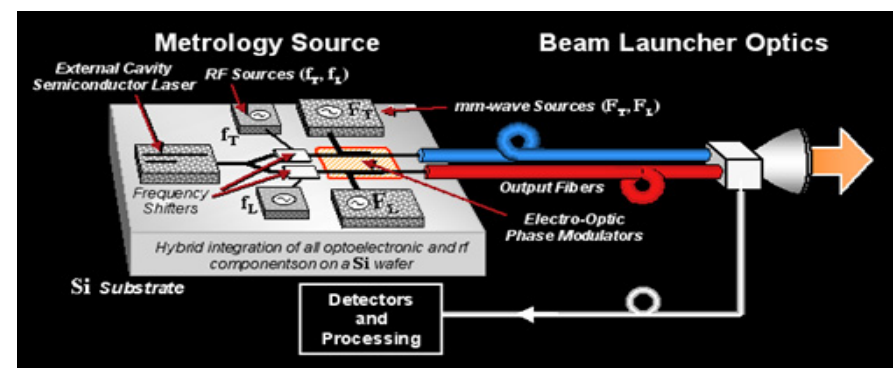
Precision formation flying dynamics simulations



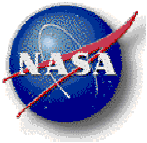
Distributed spacecraft testbeds to validate control algorithms



Equations of motion for spacecraft formations at Lagrange points



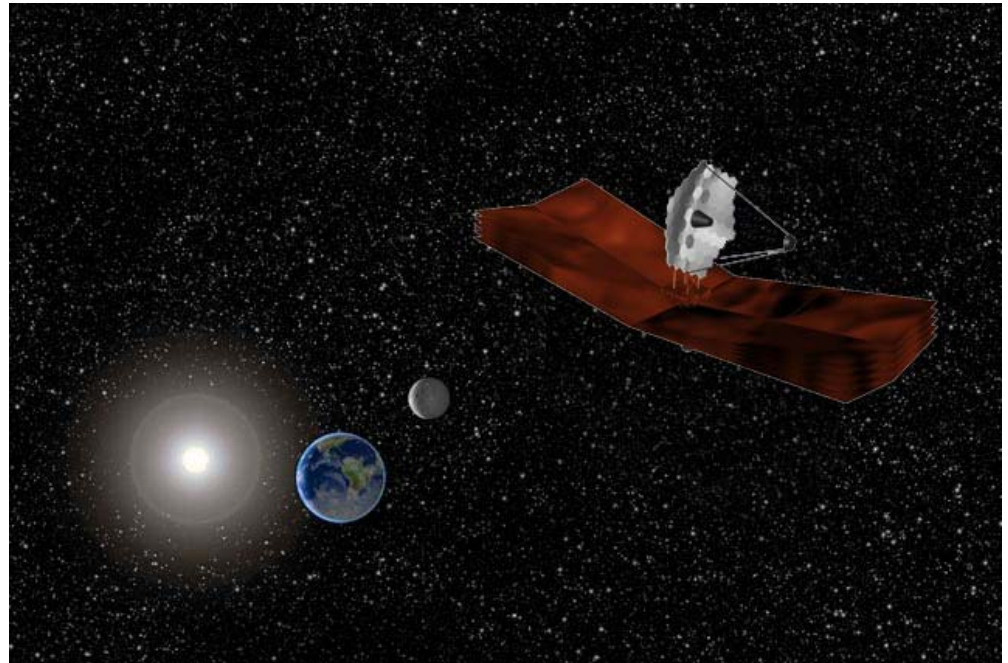
Spacecraft ranging and formation control sensors



# Technology Assessments

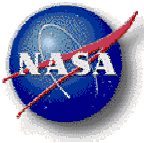


- The ECT Program uses technology assessments to identify and prioritize high-payoff technologies, to establish system-level performance goals, and to guide program investment decisions.
- Performing a pilot technology assessment study on Large Telescope Systems for Code S. Initial results expected in August.
- Pilot study involves 25 astronomers to define the scientific measurement capabilities for three aperture sizes:
  - 10 m telescope
  - 35 m telescope
  - 100 m telescope



## *Large Telescope System Technologies:*

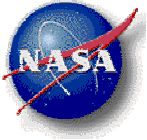
- Modular structures
- Robotic assembly
- Lightweight optics
- Active figure control
- Thermal management
- Detectors
- Formation Flying



# NASA Research Announcements



- Code R will issue a \$39M NASA Research Announcement (NRA) for Mission and Science Measurement Technology on August 4.
- The NRA will include three main technology areas in response to Enterprise priorities:
  - Advanced Measurement & Detection
    - focal planes, cryocoolers
  - Large Apertures
    - lightweight optics, wavefront control, deployable antennas
  - Low Power Electronics
- Draft NRA is posted the web for public comment at:  
<http://research.hq.nasa.gov/>
- Bidders Conference will be held at University of Maryland Conference Center on July 15.
- NRA is open to all categories of organizations, including industry, universities, non-profit institutions, NASA Centers, and other government agencies.
- Typical funding awards are \$300K - \$500K per year for 3 years.



# Summary



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The Code R Mission and Science Measurement Theme develops high-payoff crosscutting technologies to meet the future mission needs of the NASA Enterprises.

The Code R Mission and Science Measurement Theme is working closely with the Enterprises to define program content, to transition technology products, and to assess technology requirements.